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Population Density and Home Range Estimates of Black Rat (*Rattus rattus*) Populations in Southwestern Puerto Rico

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ABSTRACT: Black rats are among the world's most invasive rodent species and are responsible for considerable agricultural losses and risks to human health through zoonotic disease. In Puerto Rico, rats may also compete with the primary rabies reservoir (the small Indian mongoose) for baits during oral rabies vaccination (ORV) programs. We evaluated black rat population density and home range size on the Cabo Rojo National Wildlife Refuge, southwestern Puerto Rico. We fitted 10 rats with VHF transmitters and tracked them using radio telemetry for approximately 4 weeks. We entered locations into ArcGIS and obtained minimum convex polygon (MCP) home range estimates. We established two plots of 55 snap traps and performed removal for 5 consecutive days during January and July, to correspond roughly with wet and dry seasons for this region. To calculate abundance, we entered snap trap data using a removal model approach in Program MARK. We calculated the effective trapping area by creating a buffer around the trapping area based on the square root of mean home range estimate. We divided the abundance calculated in MARK by the effective trapping area to calculate the estimated population density. Mean MCP home range estimate was 0.28 ha (SE: 0.05, range: 0.07-0.50 ha). Population density estimates were 114.7 (SE: 201.80) and 19.3 (SE: 6.85) per ha for January and July, respectively. To reduce the potential for rat consumption of ORV baits, wildlife managers should consider conducting ORV activities in Puerto Rico during periods of lower rat abundance or density.

KEY WORDS: abundance, black rat, home range, oral rabies vaccination, population density, Puerto Rico, radiotelemetry, *Rattus rattus*, tracking tunnel

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INTRODUCTION

Rats (*Rattus* spp.) are among the world's most damaging invasive species, particularly to island ecosystems (Towns et al. 2006, Shiels et al. 2014). Not only are they responsible for declines in native flora and fauna, but rats also cause significant damage to agriculture either through direct consumption or contamination of stored food resources by urine or feces (Witmer and Singleton 2010). In addition, in some regions rats are also vectors of zoonotic diseases such as leptospirosis, bubonic plague, and lungworm, among others (Twigg 1978, Koizumi et al. 2009, Jarvi et al. 2014). Given their opportunistic and omnivorous nature, rats may act as bait competitors during bait applications intended for other species. Research by Dexter and Meek (1998) found toxic bait consumption by rats intended for foxes of up to 10.5%. However, it is unknown whether consumption was due to increased bait availability as a result of a decline in fox populations due to toxic bait consumption. Information on rats as non-target bait competitors is scarce. Bait consumption in relation to rats is more often discussed within the context of rat eradication or population control efforts where rats are the intended target. Furthermore, bait uptake by non-target species that are also non-native invasive pests may be under-reported.

The small Indian mongoose (*Herpestes auropunctatus*) is a non-native, invasive pest species and rabies reservoir in Puerto Rico and several other Caribbean islands (Everard and Everard 1992, Berentsen et al. 2015). No oral rabies vaccination (ORV) program exists for mongooses but research suggests ORV may be possible (Vos et al. 2013). When designing an ORV program, one question that needs to be addressed is the potential uptake of ORV baits by non-target species. In Puerto Rico, rodents, mongooses, and two species of primate are the only terrestrial mammalian wildlife species, none of which are native to the island. Other non-target species may include domestic dogs, cats, and livestock, none of which have as extensive distribution as rodents, which are ubiquitous in some parts of Puerto Rico (Shiels and Ramírez de Arellano 2018). Thus, rodents, primarily black rats (*R. rattus*), may play a role as a non-target competitor for ORV baits (Berentsen et al. 2014). More recent research suggests that up to 50% of ORV baits may be removed by rodents (Berentsen, unpubl.).

Bait consumption by non-target species has implications for ORV application rates and bait availability to the target species. Population density estimates of the non-target species may help guide ORV application by timing such applications during the time of year where non-target species abundance or population densities are at their lowest. Our objective was to use VHF radio telemetry to obtain home range estimates and snap trapping of rats to calculate an abundance and population density estimate for black rats in southwestern Puerto Rico.

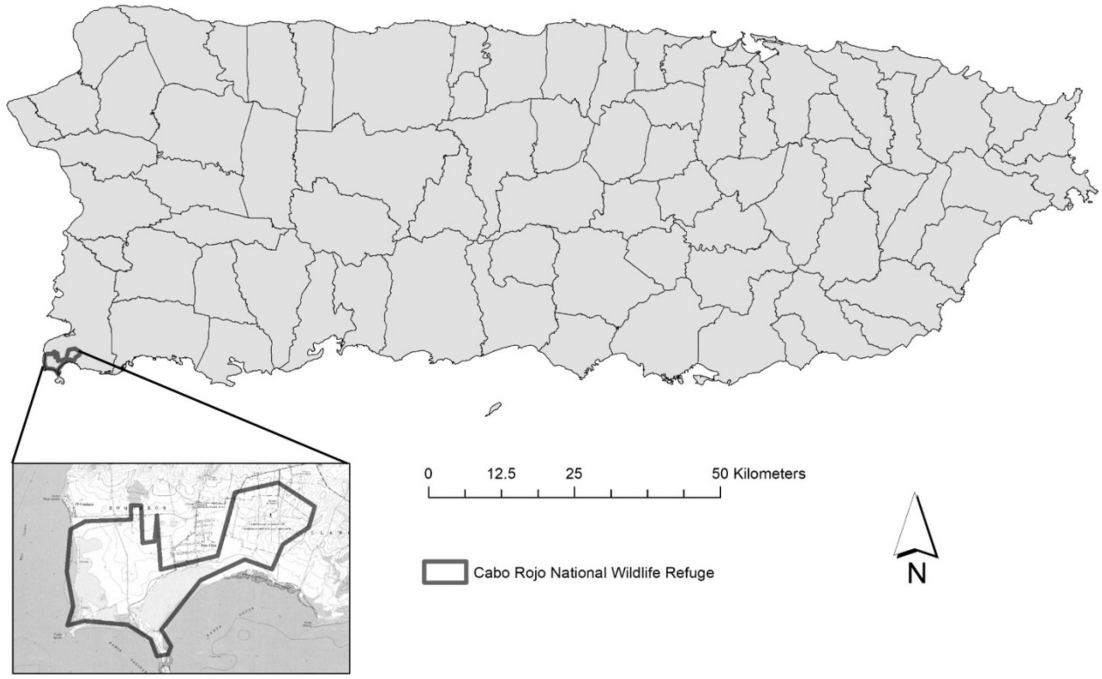

Figure 1. Cabo Rojo National Wildlife Refuge, Puerto Rico.

We also used tracking tunnels to evaluate rodent activity.

METHODS

Study Site

We conducted this study at the Cabo Rojo National Wildlife Refuge, Cabo Rojo Municipality in southwestern Puerto Rico (Figure 1). We selected two sites: the central refuge and the salt flats (Figure 2). The habitat is a sub-tropical dry forest with annual temperatures ranging from 25-32°C. Dominant vegetation consists of mesquite, semi-evergreen woodland, deciduous woodland, and coastal shrub (USFWS 2011). Annual rainfall is approximately 114 cm, much of which falls between August and November, although rain may be common throughout the year.

Tracking tunnels

We placed 121 tracking tunnels (11 × 11 grid, 30 m between tunnels) at each site during November / December 2015, and March/April 2016 (6-8 weeks pre- and post-snap trapping, respectively) and in June 2016 (Figure 3). Tracking tunnels were made of rigid, water-resistant sign board measuring 35.6 × 11.4 × 24.1 cm (Cole Graphic Solutions, Tacoma, WA). We baited tunnels with fresh coconut and applied a small strip of paper (~2 inches wide) containing a shoe polish/mineral oil mixture to either side of the bait to record tracks. We staggered tunnel placement by setting 3-5 transects at a time and completed checking the transects over a 1-week period. We checked tunnels after 24 and 48 hours and recorded the number of tunnels visited and identified species when possible. We replaced tracking ink between days.

Figure 2. Location of Salt Flats and Central Refuge study sites, Cabo Rojo National Wildlife Refuge, Puerto Rico.

Snap Trapping

We established 5 transects (a subset of the tunnel locations) with 11 snap traps per transect at each site in January and July, 2016 (Figure 3). We also opportunistically conducted trapping at the Salt Flats in December 2017, following Hurricane Maria. We placed traps 30 m apart, with 60 m between transects. The total area of the trapping grid was 7.2 ha (0.072 km^2). We attached snap traps baited with fresh coconut to tree trunks, branches, and shrubs approximately 1 m off the ground. We set traps in the afternoon approximately 1 hour before sunset

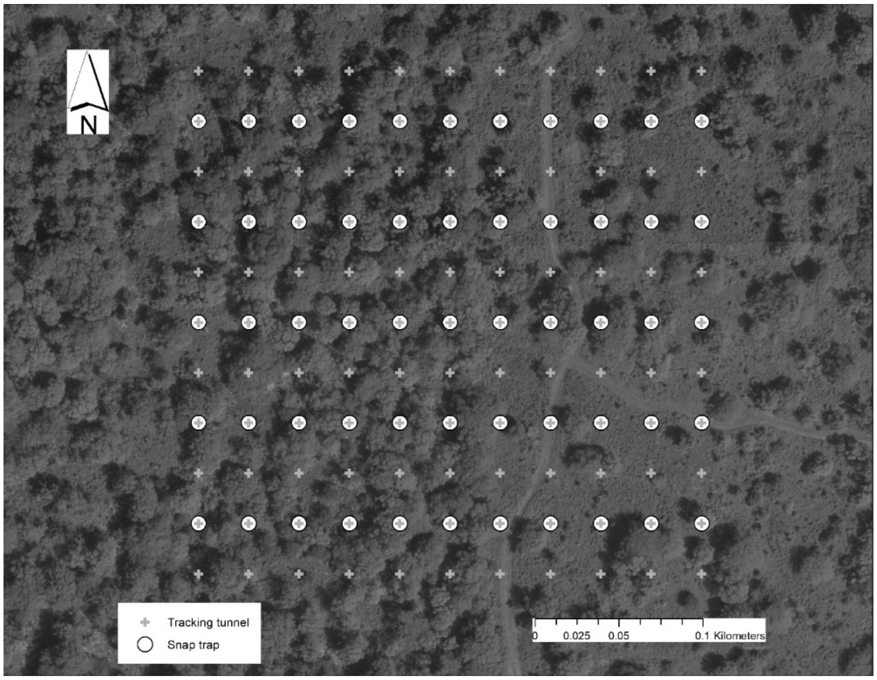

Figure 3. Example of snap trap grid and tracking tunnels, Cabo Rojo National Wildlife Refuge, Puerto Rico.

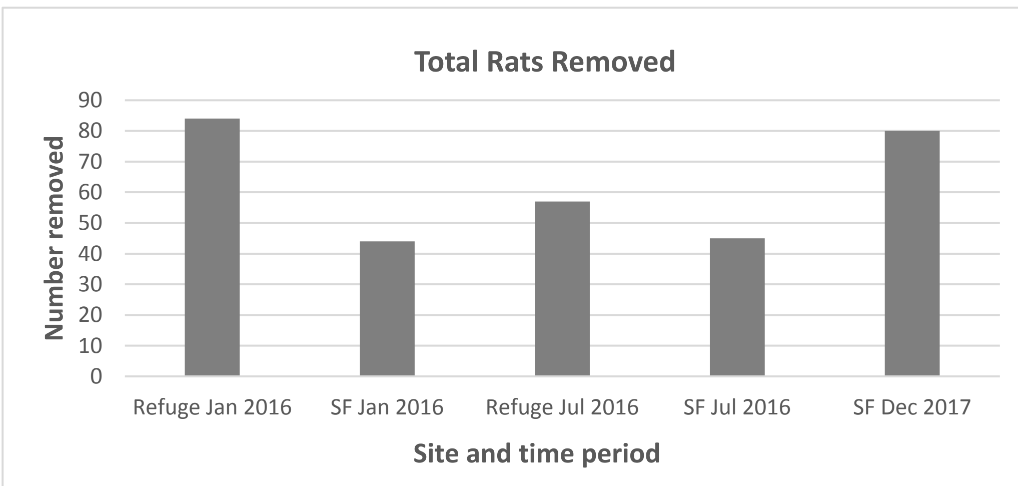

Figure 4. Total number of rats removed during 5 consecutive days of trapping in January and July, 2016 and December 2017, at the Cabo Rojo National Wildlife Refuge, Puerto Rico.

and checked them at sunrise the following morning for 5 consecutive days. We reset and rebaited traps as needed.

Radio Tracking

In January-February 2017 we live-captured rats with Sherman traps baited with fresh coconut. Traps were set in the late afternoon, approximately 1 hr hour before sunset and were checked the following morning just after sunrise. We physically restrained captured rats and fitted them with a VHF radio collar (model M1510, Advanced Telemetry Systems, Isanti, MN) weighing approximately 2.4 g. We tracked rats via radio telemetry after sunset at least once nightly, up to 3 times per week for approximately 4 weeks. Two simultaneous bearings were obtained and the rat location was determined using Location of a Signal (LOAS v4.0; Ecological Software Solutions, LLC, Hegymagas, Hungary) and the “best biangulation” option. We also recorded locations by direct observation. We entered individual rat locations into ArcGIS v10.3 (ESRI, Redlands, CA) and calculated 100% minimum convex polygon (MCP) home ranges using the Minimum Bounding Geometry tool and Convex Hull geometry type.

To calculate abundance we used a removal model approach (Zippin 1958) which jointly estimates capture rate and initial population size. We implemented the removal model in Program MARK (White and Burnham 1999) using the closed population model and setting the recapture rate to zero (White et al. 1982). We accounted for variation in sampling effort by calculating the daily proportion of traps available by dividing the number of traps found closed with no captures by the number of

Table 1. Proportion of tracking tunnels with and without activity 6-8 weeks prior to, 6-8 weeks following, and 5 months following rat removal.

Location	Salt Flats		Refuge		Salt Flats		Refuge		Salt Flats		Refuge	
Time Period	6-8 weeks pre-removal		6-8 weeks pre-removal		6-8 weeks post-removal		6-8 weeks post-removal		5 months post-removal		5 months post-removal	
Species	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Rat	8.3%	12.4%	14.9%	12.4%	18.2%	37.2%	33.1%	45.5%	23.1%	22.3%	60.3%	66.9%
Mouse	2.5%	4.1%	14.0%	22.3%	58.7%	70.2%	51.2%	59.5%	6.6%	14.0%	51.2%	81.8%
Cat	1.7%	0.8%	0.0%	0.0%	1.7%	0.8%	2.5%	0.8%	2.5%	3.3%	0.8%	0.8%
Mongoose	2.5%	2.5%	2.5%	8.3%	25.6%	12.4%	16.5%	18.2%	24.8%	36.4%	43.0%	46.3%
No tracks	81.0%	79.3%	67.8%	54.5%	0.0%	0.0%	24.8%	14.9%	52.9%	37.2%	11.6%	2.5%

traps. We calculated the mean home range size and added the square root of mean home range size to the length and width of the trapping grid to create and effective trapping area. We divided the abundance estimates by the effective trapping area to calculate the estimated population density and used the Delta method to calculate the variance for the density estimates (Powell 2007).

RESULTS

We captured and radio-collared 10 rats and obtained an average of 26 locations per rat (range: 18-31). Average MCP home range estimate was 0.28 ha (SE: 0.05, range: 0.04-0.50 ha). Due to low overall snap-trap success at individual sites, we combined sites for abundance and population density estimates. The overall number of rats trapped was fairly consistent over the 5-day trapping periods (Figure 4). January abundance was 1,170 (SE: 2,058.4; 95% CI: 216.0-12,462.3) and abundance for July was 196.8 (SE: 69.9; 95% CI: 128.1-446.7). Population density estimates were 114.7 per ha (SE: 201.80; 95% CI: 21.2-1,221.8/ha) and 19.3 per ha (SE: 6.85; 95% CI: 12.6-43.8/ha) for January and July, respectively. Abundance estimates at the Salt Flats for December 2017 (following Hurricane Maria) were 5,168.4 (SE: 23,224.3; 95% CI 242.9-159,035.4) with a population density estimate of 506.7 per ha (SE: 2,276.9; 95% CI: 23.8-15,591.7/ha). Due to access issues associated with hurricane damage, we were unable to obtain abundance and population density estimates at the central refuge.

Tracking tunnels were visited by rats, mice, mongooses, and domestic cats. Many tracking tunnels had track from multiple species. Tracking tunnel activity from all species increased following rodent removal and remained high through the final sampling period in June 2016 (Table 1).

DISCUSSION

Many factors can influence rodent home range size and population density, including season, breeding frequency, and habitat heterogeneity, among others (Ringler et al. 2014). In our study population, density estimates were almost 6 times higher in January than in July and over 25 times higher in December, following Hurricane Maria. January is the tail end of the rainy season and population densities could be higher as a result of increased food resources or prevalence of juveniles. With the exception of the December 2017 estimate, population densities were lower than expected when compared to other tropical/subtropical islands. For example, population density estimates for black rats on Diego Garcia, British Indian Ocean Territory were as high as 187 per ha in some habitats (Vogt et al. 2014). The precise reasons for the extraordinary population density estimate in December 2017 (approximately 3 months following Hurricane Maria) are unknown but may be related to increased foraging as a result of limited food resources, thus making our baited traps attractive following a natural disaster. Average home range estimate was larger than those reported in other areas such as islands in the SW Indian Ocean (0.003-0.18 ha; Ringler et al. 2014), and reports from New Zealand (0.01-0.05 ha; Innes and Skipworth 1983). However, differences in habitat type and methodology must be taken into consideration when making comparisons.

The activity index provided by the tracking tunnels showed an increase in activity by rodents and mongooses over time. Tunnel visitation on day 2 of the November/December 2015 monitoring period was 12.4% and 13.2% for rats and mice, respectively. By day 2 of the March/April 2016 monitoring period, activity increased to 41.3% and 65.7% for rats and mice, respectively and remained high until the final monitoring period in June 2016. While repopulation following removal may be one explanation for this increase in rodent activity, it does not explain the increase in mongoose activity, as no mongooses were removed. It is interesting to note that rat activity seemed to increase in the spring and early summer when population density appeared to decrease. The precise reasons for this discrepancy remain unknown and would require longer-term research beyond the scope of this study.

When interpreting results from our study, we must take into consideration its limitations. Our radio tracking, snap trapping, and tracking tunnel evaluations were conducted during short windows in time and only during a 1-year period with limited replication. Our results may or may not be representative of other years or months within a single year. The population density estimates are highly variable, likely a result of relatively low trap success resulting in a limited sample size. The home range estimates generated in this study were similarly limited. Seaman et al. (1999) recommend at least 30 locations per animal to generate an accurate home range estimate, and preferably >50 locations, whereas we obtained 18-31 locations. While not optimal, our home range estimates were the result of 4 weeks of tracking during only one season and may not be representative of rat activity during different times of year. However, our objective was not to conduct a long-term study of rat home ranges, but to provide a basic measurement to include as an effective trapping area when calculating the population density estimate.

Despite the limitations described above, we believe this study has provided valuable insights into rodent abundance and population density with respect to ORV application. Lower rat abundance and population density during July suggests the summer, when rainfall may be less common, may be a more efficient time to apply ORV baits to reduce potential competition for baits by rats. Interestingly, population density of mongooses, the ORV target species, also tends to be lower during this period (Johnson et al. 2016) though the magnitude in difference (~10-15%) is not as great as what we observed for rats. While eliminating non-target bait consumption completely during any type bait application (ORV, toxicant, etc.) is unlikely, paying close attention to timing such bait applications with respect to population density of target and non-target species may help maximize bait uptake by target species.

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LITERATURE CITED

Berensten, A. R., S. R. Johnson, A. T. Gilbert, and K. C. VerCauteren. 2015. Exposure to rabies in small Indian mongooses (*Herpestes auropunctatus*) from two regions in Puerto Rico. Journal of Wildlife Diseases 51:896-900.

Berentsen, A. R., S. R. Johnson, and K. C. VerCauteren. 2014. Bait matrix flavor preference by mongoose (*Herpestes auropunctatus*) in Puerto Rico: implications for oral rabies vaccination. Caribbean Journal of Science 48:52-58.

Dexter, N., and P. Meek. 1998. An analysis of bait-take and non-target impacts during a fox-control exercise. Wildlife Research 25:147-155.

Everard, C. O. R., and J. D. Everard. 1992. Mongoose rabies in the Caribbean. Annals of the New York Academy of Sciences 653:356-366.

Innes, J. G., and J. P. Skipworth. 1983. Home ranges of ship rats in a small New Zealand forest as revealed by trapping and tracking. New Zealand Journal of Zoology 10:99-110.

Jarvi, S., W. Pitt, A. Osuna, M. Farias, L. Shiels, K. Howe, S. Jacquier, A. Shiels, K. Amano, B. Luiz, D. Maher, M. Allison, Z. Holtquist, N. Scheibelhut, M. Severino, and L. Riddick. 2014. Efficacy of a vaccine for *Angiostrongylus costaricensis* against rat lungworm disease caused by *A. cantonensis* in wild Hawaiian rats (*Rattus rattus*) (VAC7P.978). Journal of Immunology 192 (Suppl. 1):141 .23.

Johnson, S. R., A. R. Berentsen, C. Ellis, A. Davis, and K. C. VerCauteren. 2016. Estimates of small Indian mongoose densities: implications for rabies management. Journal of Wildlife Management 80:37-47.

Koizumi, N., M. Muto, T. Tanikawa, H. Mizutani, Y. Sohmura, E. Hayashi, N. Akao, M. Hoshino, H. Kawabata, and H. Watanabe. 2009. Human leptospirosis cases and the prevalence of rats harbouring *Leptospira interrogans* in urban areas of Tokyo, Japan. Journal of Medical Microbiology 58:1227-1230.

Powell, L. A. 2007. Approximating variance of demographic parameters using the Delta Method: a reference for avian biologists. The Condor 109:949-954.

Ringler, D., J. Russell, A. Jaeger, P. Pinet, M. Bastien, and M. Le Corre. 2014. Invasive rat space use on tropical islands: implications for bait broadcast. Basic and Applied Ecology 15:179-186.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739-747.

Shiels, A. B., W. C. Pitt, R. T. Sugihara, and G. W. Witmer. 2014. Biology and impacts of Pacific island invasive species. 11. *Rattus rattus*, the black rat (Rodentia: Muridae). Pacific Science 68:145-184.

Shiels, A. B., and G. E. Ramírez de Arellano. 2018. Invasive rats (*Rattus rattus*) but not always mice (*Mus musculus*) are ubiquitous at all elevations and habitats within the Caribbean National Forest, Puerto Rico. Caribbean Naturalist 48:1-14.

Towns, D. R., I. A. E. Atkinson, and C. H. Daugherty. 2006. Have the harmful effects of introduced rats on islands been exaggerated? Biological Invasions 8:863-891.

Twigg, G. I. 1978. The role of rodents in plague dissemination: a worldwide review. Mammal Review 8:77-110.

United States Fish and Wildlife Service. 2011. Draft comprehensive conservation plan and environmental assessment: Cabo Rojo National Wildlife Refuge, Cabo Rojo, Puerto Rico.

Vogt, S., A. N. Guzman, and E. Necessario. 2014. Rat density on Diego Garcia. Unpublished report to the United States Naval Facilities Engineering Command, US Naval Support Facility, Diego Garcia, British Indian Ocean Territory.

Vos, A., A. Kretzschmar, S. Ortmann, I. Lojkic, C. Habla, T. Müller, C. Kaiser, B. Hundt, and P. Schuster. 2013. Oral vaccination of captive small Indian mongoose (*Herpestes auropunctatus*) against rabies. Journal of Wildlife Diseases 49:1033-1036.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, Los Alamos, NM.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. https://doi.org/10.1080/00063659909477239.

Witmer, G., and G. Singleton. 2010. Sustained agriculture: the need to manage rodent damage. Pages 1-39 *in* F. Wager, editor. Agricultural Production, Nova Science Publications, New York, NY.

Zippin, C. 1958. The removal method of population estimation. Journal of Wildlife Management 22:82-90.